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Task 4 Supporting Technology
Detailed Test Plan for Thermal Seals

Payment Milestone No. LE01 Part 2 of 2

WBS 1840

Cooperative Agreement NCC8-79

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Detail Test Plan - DTP 6668-801

Thermal Seals Evaluation, Improvement and Test

CAN8-1, Reusable Launch Vehicle (RLV), Advanced Technology Demonstrator: X-33
Leading Edge and Seals Thermal Protection System Technology Demonstration
Cooperative Agreement NCC8-79

Task Leader: Tina Lu
May 24, 1995

1.0 OBJECTIVE

The objective of this program is to develop the advanced thermal seals to a technology readiness level (TRL) of 6 to support the rapid turnaround time and low maintenance requirements of the X-33 and the future reusable launch vehicle (RLV). This program is divided into three subtasks. Subtask 1 and part of Subtask 2 will be performed in FY '95, the remaining of Subtask 2 and Subtask 3 will be completed by the end of FY '96 if full Task 4 Technology funding becomes available.

2.0 BACKGROUND

The thermal protection system (TPS) is critical to the survivability and performance of a reentry vehicle. The durability and ease of maintenance of that TPS are major contributors to the operational cost and turnaround time of the vehicle. Thermal seals are a part of the TPS which acts as a barrier against any potential hot gas leaking through penetrations during the severe ascent and reentry environment. Some examples of the penetrations include payload bay doors, landing gear doors, ports for attaching umbilical, vent and access panels. The refurbishment and fabrication of seals and their installation are labor intensive. The thermal seals are critical to vehicle performance and present significant technical challenges for X-33 / RLV requirements for low cost and short turnaround time. These components are not covered by any ongoing technology effort. The approach of this particular task is to develop improved materials, processes, and designs for thermal seals utilizing the current technology as a baseline. The goal is to yield a lower-cost, reduced-maintenance, and lighter-weight TPS subsystem for the requirements of X-33 / RLV.

The results of the development and optimization of the advanced thermal seals will be demonstrated in flight on the X-33 in phase II and be ready for the Phase III RLV technology. This task schedule is coordinated with the X-33 design and analysis tasks. The results of the X-33 system study will provide the test requirements for this task.

This task is divided into three subtasks. This detail test plan (DTP) begins with a general objective section, a general background section and a general requirement section for the entire task, followed by details of each of the subtasks which contain introduction, applicable documents, detailed requirements, and applicable fabrication / test article description, fabrication / test procedures, equipment, sketches / schematics and schedule. Some of the subtasks do not involve testing and the sections are modified to reflect the nature of the subtask. In subtasks which require testing of the material, DTP of the test will be referenced and attached n the Appendix section.

3.0 GENERAL REQUIREMENT

3.1 Documentation

3.1.1 Detailed test procedure (DTP)

All testing will be conducted in accordance with this test procedure.

3.1.2 Laboratory Notebook

A Laboratory Notebook will be maintained by the Rockwell Responsible Test Engineer (RTE) depicting a complete test history. Test article configuration, instrumentation, test anomalies and all other pertinent data and information will be recorded.

3.1.3 Test Report

The test agency will issue a Laboratory Test Report (LTR). The test report will depict the complete test program, instrumentation, test procedures and results, test setup, photographs, test data and any other pertinent information.

3.2 Test Facility

Test equipment and facilities will be utilized at both government and industry facilities. Appropriate facilities will be selected to simulate the interaction of identified adverse environments. Test facilities which have been identified are listed below.

- NASA-Ames arc jet facilities, 60 or 20 MW facilities
- Rockwell Materials and Processes Laboratories
- Rockwell radiant heat facility

Schedules and test requirements are defined in the detailed test description section of this document.

3.3 Instrumentation

All measurement instrumentation shall be calibrated and have a decal showing a valid calibration date. A list of all test instrumentation will be maintained in a Laboratory Notebook.

3.4 Test Conduct

The test program will be conducted under the direction of the task leader or a designated representative.

4.0 SUBTASK DESCRIPTION

The approach for improving the operational characteristics of thermal seals while preserving their primary function includes the improvements of materials, processes, and design of the current technology. This task can be divided into three subtasks. The first subtask is to perform a detailed review of Orbiter thermal seal operational history to identify the areas in which improvements will provide the greatest return. The second subtask is to propose material, process and design improvements. Advanced ceramic materials from RLV technologies will be included in the thermal seal material and process development. Design improvements recommended by Rockwell engineers at the Kennedy Space Center (KSC) will be reviewed and incorporated into demonstration and test articles. The third subtask is to fabricate the new thermal seals with the improved concepts and to perform mechanical and thermal testing. The subtasks will be described in detail in Sections 4.1 through 4.3.

- Orbiter thermal seals operation history review (4.1)
- Materials, process and design improvements (4.2)
- Fabrication and evaluation of the advanced thermal seals (4.3)

4.1 Orbiter thermal seals operation history review

4.1.1 Introduction

Previous and current work on thermal seals improvement has been limited to the Orbiter and NASP. The primary advancement has been in segmenting the main landing door seal and changing the attachment method from adhesive bonding to mechanical fasteners. The thermal seals currently in use on the Orbiter and those developed or proposed for NASP will be reviewed for material, design, performance, damage frequency, and type of damage. Areas in which improvements in materials, installation processes, or design will lead to improved operational efficiency (improved life, decreased maintenance, lower time to repair, damage resistance, etc.) will be identified. These areas will be used as a basis for fabricating and testing improved thermal seals.

4.1.2 Applicable Documents

- Proposal to CAN8-1, Reusable Launch Vehicle (RLV), Advanced Technology Demonstrator X-33

- Cooperative Agreement - NCC8-79

- KSC Thermal Protection Systems Facility (TPSF) Test Assembly and Inspection Record (TAIR) Index

- KSC Automated Work Control System (AWCS)

- TPS Post Flight Assessment Reports

- Lockheed-Martin Shuttle Processing Contractor (SPC) TAIR Index

- Design Enhancement Study / resource book

4.1.3 Requirements

This subtask is mainly on research and data review. A documentation of the study results will be provided by the end of this subtask.

4.1.4 Schedule

- **Complete data review** **6/30/95**

4.2 Material, process, and design improvements

4.2.1 Introduction

Newer, more durable ceramic fabric materials, such as 3M's Nextel 440 and 550, will be evaluated for use as thermal seals. Technologies under development for use as advanced blankets in RLV concepts and Orbiter upgrades will be used in this X-33 thermal seals program. Compression characteristics will be obtained from knitted Inconel wire tubing with ceramic batting inside the tubing. With the information obtained from the data review and tests, materials, processes and design candidates will be evaluated and ranked. Promising combinations will be selected for development.

Since some repair and/or removal and replacement is anticipated in field use, simplified thermal seal fabrication processes will be developed. In conjunction with design changes, installation processes will be improved to support a short-turnaround schedule.

The interface between mating parts, such as a door and structure, affects the requirements and design of the thermal seal. Lessons learned from the orbiter operations and in NASP studies will be applied to the X-33/RLV in order to simplify thermal seal installation and reduce the causes of thermal seal damage.

4.2.2 Applicable Documents

- Design / Stress / Thermal specifications and requirements

4.2.3 Requirements

Evaluation and analysis to optimize thermal, process, and design of the advanced thermal seals will be performed with support from different functions (e.g. design, M&P, thermal, stress, KSC engineers). Proposed materials, process and design modifications will be made at the conclusion of the subtask.

4.2.4 Schedule

- **New seal materials selected** **12/15/95**

4.3 Fabrication and Evaluation of the Advanced Thermal Seals

4.3.1 Introduction

Thermal seals with new materials, processes, and design concepts will be fabricated. Laboratory evaluations of their thermal and mechanical performance will be performed by radiant heat exposure and compression testing. Multiple cycles of testing will be performed to determine changes in compression recovery.

When the thermal seal materials and designs have been optimized, test articles will be designed, fabricated, and exposed to at least four cycles of arc jet testing. A cycle will consist of seal compression, arc jet exposure, structure separation, compression set measurement, and structure closure (seal compression).

4.3.2 Applicable Documents

- Laboratory Notebook
- DTPs of compression and thermal performance tests

4.3.3 Test Article Description

Test Objective	Test Article Description	No. of Test Articles	Instrumen-tation	Test Facility	Test Date
Seal compression tests	6" x 0.5" diameter specimens	10	N/A	SSD	Apr. 96
Thermal Performance	6" x 0.5" diameter specimens	2	T/Cs	NASA ARC	Jun. 96

4.3.4 Test Procedures/Equipment

See the attached venting test DTP in Appendix A as a sample for preparing the compression and thermal performance tests for this task. The DTPs will be prepared prior to the tests. The test parameters and specimen configurations will be determined by the results of the X-33 system study and subtask 4.2.

4.3.5 Schedule

New seal concept fabrication complete	**2/16/96**
New seal test article arc jet tests	**5/26/96**
Test reports and data analysis	**7/26/96**

5.0 Program Milestones

See Table I and Figure 1 for the program milestones. Only Line items 1.5.3 and 1.5.3.1 of Figure 1 are pertinent to the advanced thermal seals development.

Table I - Advanced Thermal Seals Development Milestones

Table I - Advanced Thermal Seals Development Milestones

Payment Milestone	Date	Milestone Description
LE-01	5/26/95	DTP complete
LE-07	12/15/95	New seal materials selected
LE-09	2/16/96	New seal concept fabrication complete
LE-11	5/26/96	New seal test article arc jet tests
LE-12	7/26/96	Test reports and data analysis

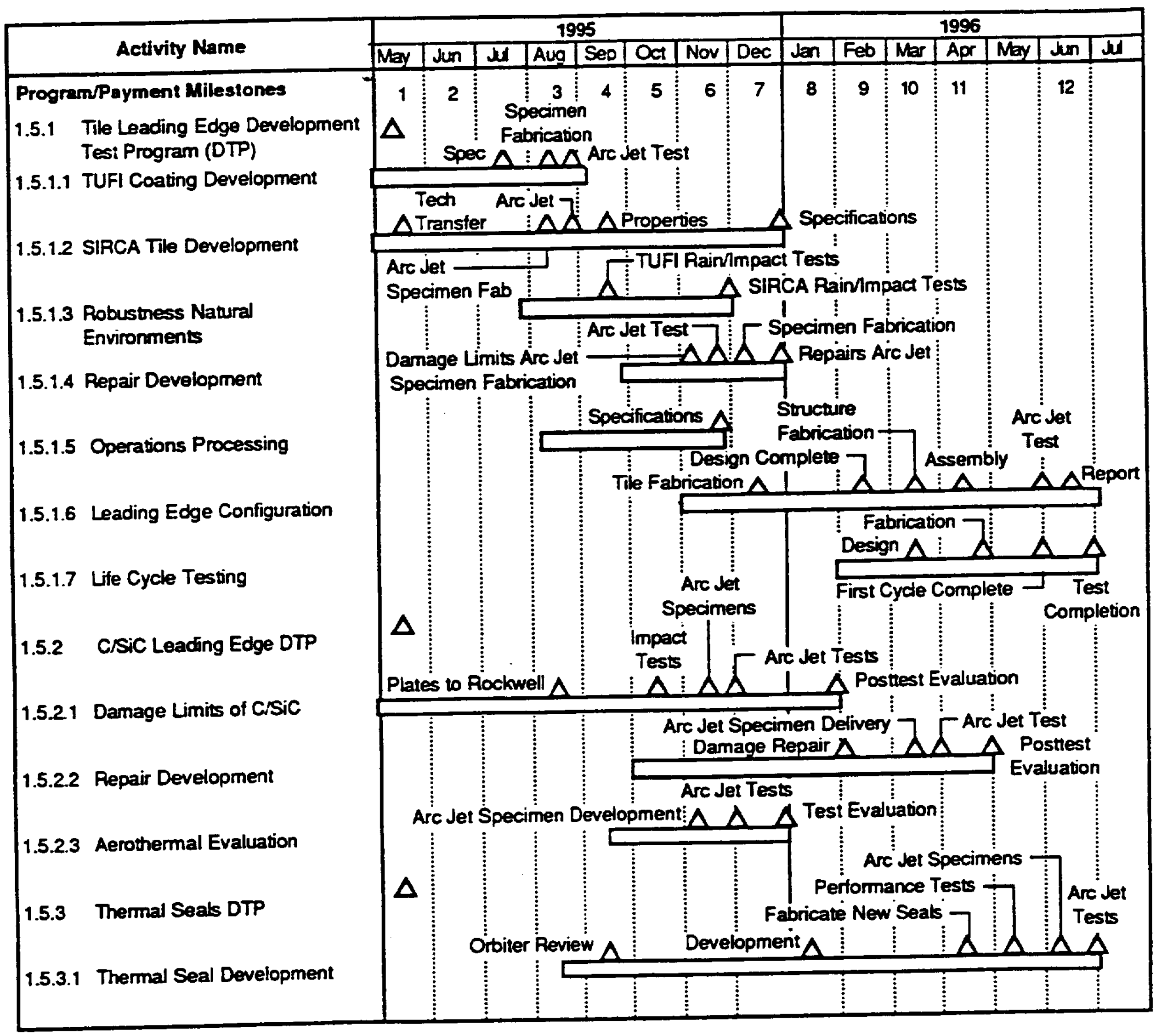

Figure 1 - Program Milestones

APPENDIX A
TPS VENTING TEST

L & T
RELEASE

LABORATORIES AND TEST
DETAIL TEST PROCEDURE
OEX-ADVANCE RIGID INSULATION (ARI)
TOUGHENED UNI-PIECE FIBROUS INSULATION VENT TEST

Prepared by: Steve B Goo
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Approved by: M J Marchisio
M. J. Marchisio, Supervisor
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KS Feldman
K. S. Feldman, Test Requester
TPS Test Design

0387L

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1.0 INTRODUCTION

A venting test program will be performed to support certification of the Toughened Uni-piece Fibrous Insulation (TUFI) Aluminum Enhanced Thermal Barrier (AETB) tile for flight test.

2.0 SCOPE

This document contains the general test requirements and the detailed test procedures required to conduct the venting test as defined in the Test Request (TR S107158).

3.0 OBJECTIVES

The objectives of this test are to determine the differential pressure (ΔP) between ambient and the interior of the test article, the pressure gradient across the interior of the tile at various depths, and if the coating on the TUFI AETB tile can withstand the differential pressure.

4.0 APPLICABLE DOCUMENTS AND DRAWINGS

The following document and drawings in effect shall form a part of this procedure to the extent specified herein. Where a conflict in the requirement exists between this document and the applicable document and drawings, the requirements of this document shall take precedence.

<u>Document</u>

TR S107158	Test Request - OEX Advanced Rigid Insulation (ARI). Toughened Uni-piece Fibrous Insulation (TUFI) Vent test.

<u>Drawings</u>

VT70-095224	ARI TUFI Tile Bell Jar Venting Assembly.
VT70-090120	TUFI Tile.
VT70-090104	LI900 Tile.

5.0 GENERAL REQUIREMENTS

5.1 Documentation

5.1.1 Detailed Test Procedure (DTP)

The test will be conducted in accordance with this procedure.

5.1.2 Laboratory Notebook

A Laboratory Notebook (Form 93-G) will be maintained by the L&T Responsible Test Engineer depicting a complete test history. Test article configuration, instrumentation, test anomalies and malfunctions and all other pertinent data and information will be recorded.

5.1.3 Test Report

The test agency will issue a Laboratory Test Report (LTR). The test report will depict the complete test program, instrumentation, brief test procedures and results, test setup including photographs, test data and other pertinent information.

5.2 Notification

The Engineering Test Coordinator shall be notified 24-hours in advance of a scheduled test.

5.3 Test Facility

The test will be conducted in Bldg. 288, Environmental Systems Laboratory.

5.4 Instrumentation

All measurement instrumentation will be calibrated and have a decal

5.4 Instrumentation - Continued

showing a valid calibration due date. A list of test instrumentation will be maintained in a Laboratory Notebook showing name/description, metrology number and calibration due date.

5.5 Test Conduct

The test program will be conducted under the direction of a test conductor who will be the L&T Responsible Test Engineer (RTE) or his designated representative.

6.0 Test Specimen

Two test tile specimens, LI 900 and TUFI AETB, will be provided for this test.

Both test tile specimens are identically instrumented with pressure tubes and will be exposed to ascent and entry pressure profiles at the same time.

Data from the LI 900 specimen will be used as reference.

CHECKLIST 1

PRETEST VERIFICATION

TASK	DESCRIPTION	COMP.
1.	Verify that all instrumentation and calibrated equipment are recorded in the Laboratory Notebook.	
2.	Verify that all pressure tubes are properly connected to pressure transducers.	
3.	Verify that all 13 pressure transducers channels indicate ambient pressure on LDS.	
4.	Photograph test specimens and the test setup.	
5.	Start the diffusion pump per Checklist 2.	
6.	O.K. to close the vacuum chamber.	
7.	This completes Checklist 1.	

CHECKLIST 2

DIFFUSION PUMP STARTUP

TASK	DESCRIPTION	COMP.
1.	Verify that the pump cooling water is on.	
2.	Start the foreline pump (FP-1 to the "ON" position).	
3.	Verify that light FP-1 on the system schematic panel is running.	
4.	Open the foreline valve (FV-1 to the "ON" position).	
5.	Verify that light FV-1 on the system schematic panel is illuminated.	
6.	Verify that the foreline pressure decreased to less than 50 microns.	
7.	Turn on the diffusion pump heater (DTP-1 to the "ON" position).	
8.	Verify that light DP-1 on the system schematic panel is illuminated.	
9.	This completed Checklist 2.	

CHECKLIST 3

ASCENT PROFILE

TASK	DESCRIPTION	COMP.
1.	Verify that the chamber door is closed.	
2.	Verify that the chamber isolation valve is in the "CLOSED'" position.	
3.	Verify that the pump position switch is in the "OFF" position.	
4.	Activate the MICON Valve Controller and 28 VDC Power Supply.	
5.	At MICON Valve Controller.	
5.1	Set Computer/Auto/Manual mode select switch to 'MANUAL".	
5.2	Set Process Feedback/Error/Valve Command switch to "Valve Command".	
5.3	Verify that lower LED display indicates 00.0% (fully closed position).	
	NOTE: If the display shows other than zero, press. Increment/Decrement switch down until the display shows zero.	
5.4	Set Process Feedback/Error/Valve Command switch to "Valve Command".	
5.5	Verify that lower LED display indicates around 95% (ambient).	
6.	Verify that Data Trak curve following probe is in the ascent profile program starting point.	
7.	Verify/position Data Trak mode select switch to "REMOTE'".	
8.	Start the 300 CFM roughing pump.	
9.	Open the chamber isolation valve.	
10.	Set the pump position switch to "PUMP VALVE OPEN"	

CHECKLIST 3

ASCENT PROFILE - Continued

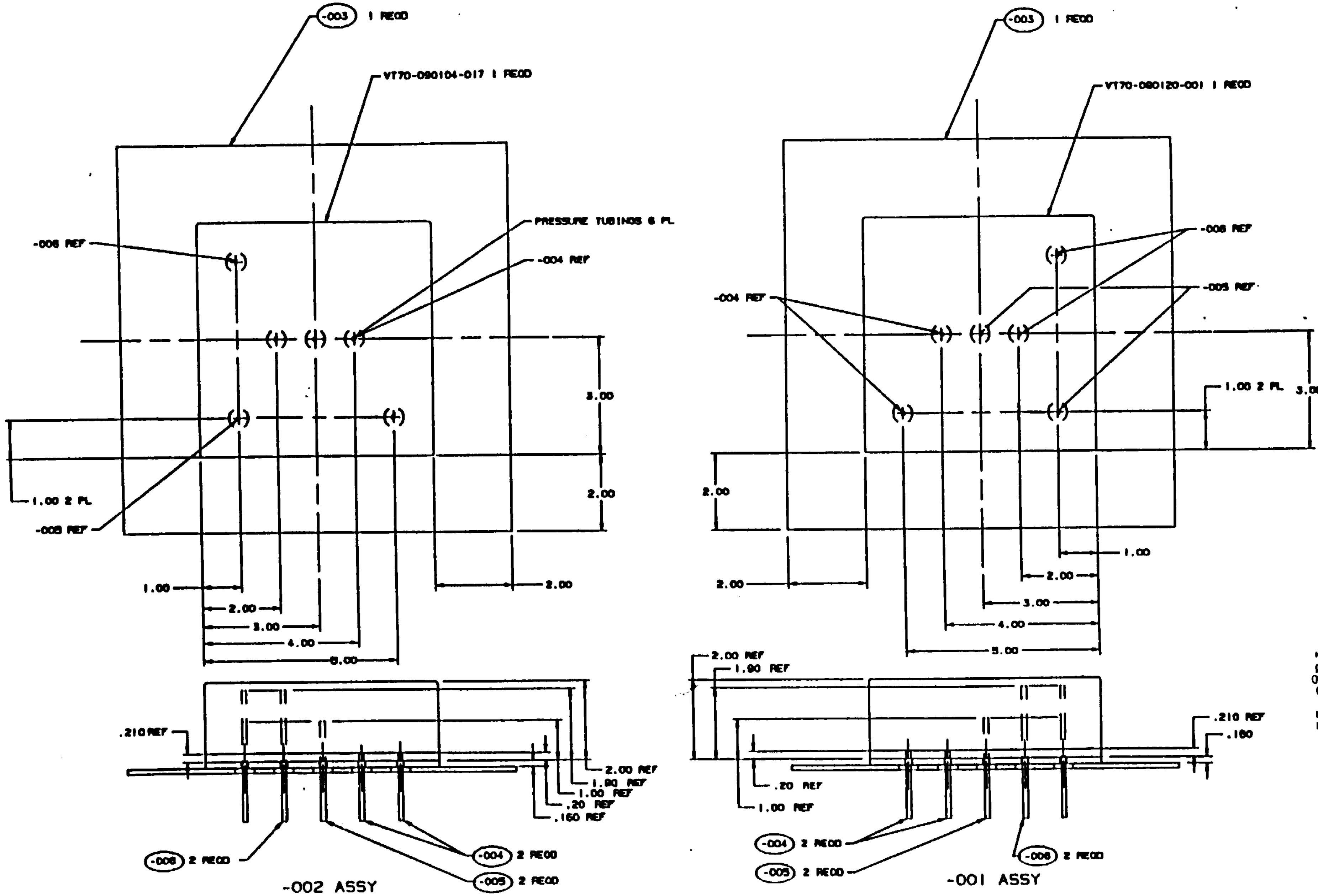
TASK	DESCRIPTION	COMP.
11.	Set LDS System at one second sample rate.	
12.	Set Data Trak mode select switch to "RUN".	
13.	Set Computer/Auto/Manual switch to auto at MICON valve controller.	
14.	Verify the proper DATA TRAK operation (Monitor the curve following probe position vs. set point).	
15.	At the completion of the ramp.	
15.1	Set Data Trak mode select switch to "RUN".	
15.2	Change LDS sampling rate to 20 second interval.	
16.	Continue to pump down the chamber until the chamber pressure reduces below 50 microns.	
17.	Set Computer/Auto/Manual switch to auto to 'MANUAL".	
18.	Set Process Feedback/Error/Valve Command Switch to Valve Command.	
19.	Press Increment/Decrement switch down until lower LED display indicates 0.00%.	
20.	Verify that the diffusion pump is ready for pumping.	
21.	Open the high vacuum valve.	
22.	Reduce the chamber pressure to 10^{-3} torr or lower. Hold for 15 minutes minimum.	
23.	Close the high vacuum valve.	
24.	Proceed to Checklist 4 to simulate entry pressure profile.	
25.	This completes Checklist 3.	

CHECKLIST 4

ENTRY PROFILE

TASK	DESCRIPTION	COMP.
1.	Verify that DATA TRAK curve following probe is in the entry profile program starting point.	
2.	Verify/Set Computer/Auto/Manual selector to "MANUAL"	
3.	Verify/Set Process Feedback/Error/Valve Command selector to "Valve Command"	
4.	Verify that lower LED display indicates zero (0.00%).	
5.	Set Process Feedback/Error/Valve Command selector to "Process Feedback".	
6.	Activate LDS at one second sample rate..	
7.	Position Data Trak mode selector to "RUN".	
8.	Set Computer/Auto/Manual selector to "AUTO".	
9.	At the completion of the ramp, secure the system as follows:	
9.1	Set Data Trak mode select switch to 'HOLD".	
9.2	Set Computer/Auto/Manual switch to "MANUAL".	
9.3	Set Process Feedback/Error/Valve Command switch to "VALVE COMMAND".	
9.4	Verify that lower LED display indicates zero.	
9.5	Verify that the pump position switch to "PUMP VALVE CLOSE". (ambient).	
9.6	Turn off the 300 CFM roughing pump.	
10.	This completes Checklist 4.	

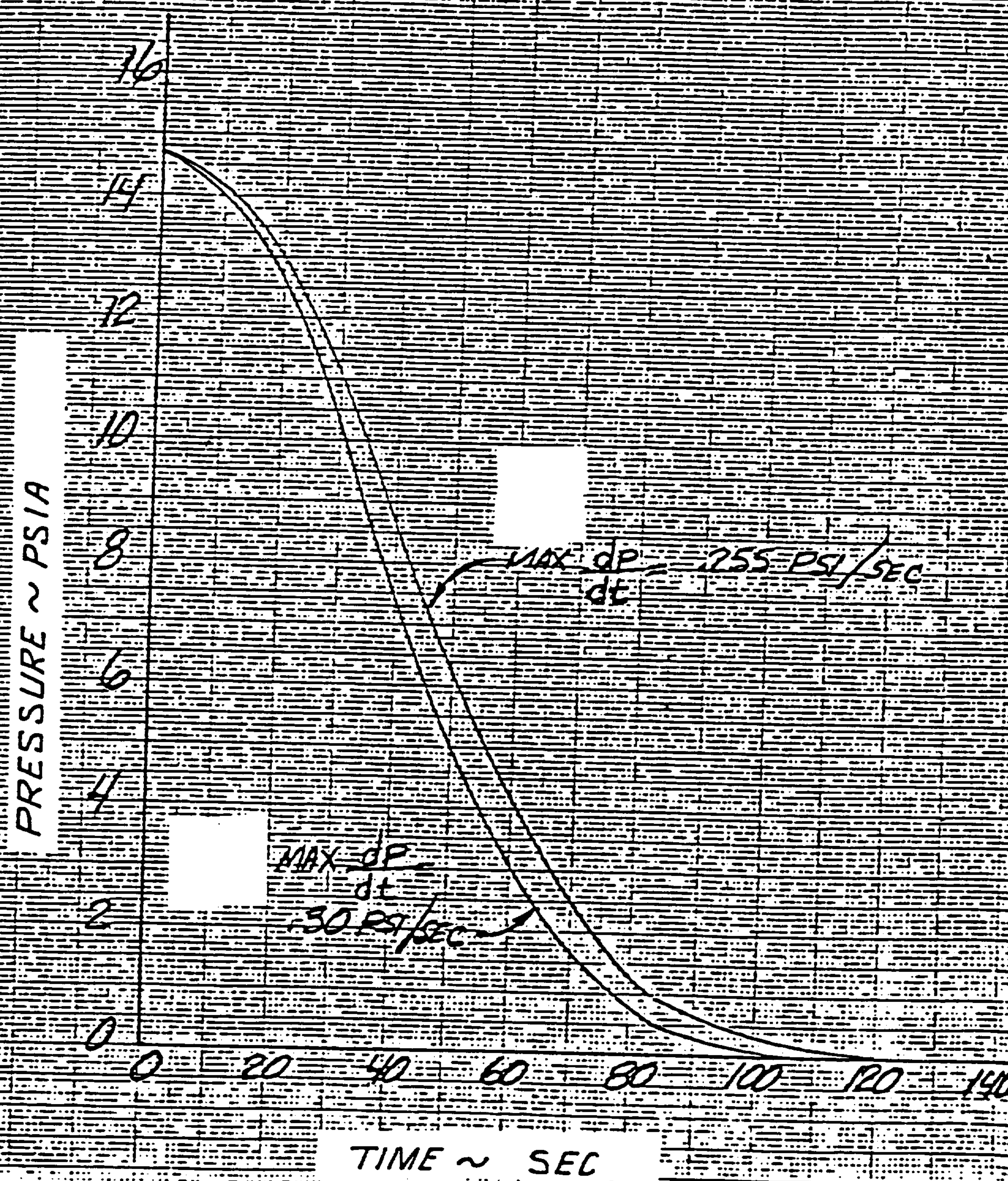
TEST SPECIMENS
FIGURE 1



ORBITER ASCENT MISSIONS

AMBIENT PRESSURE BOUNDARIES

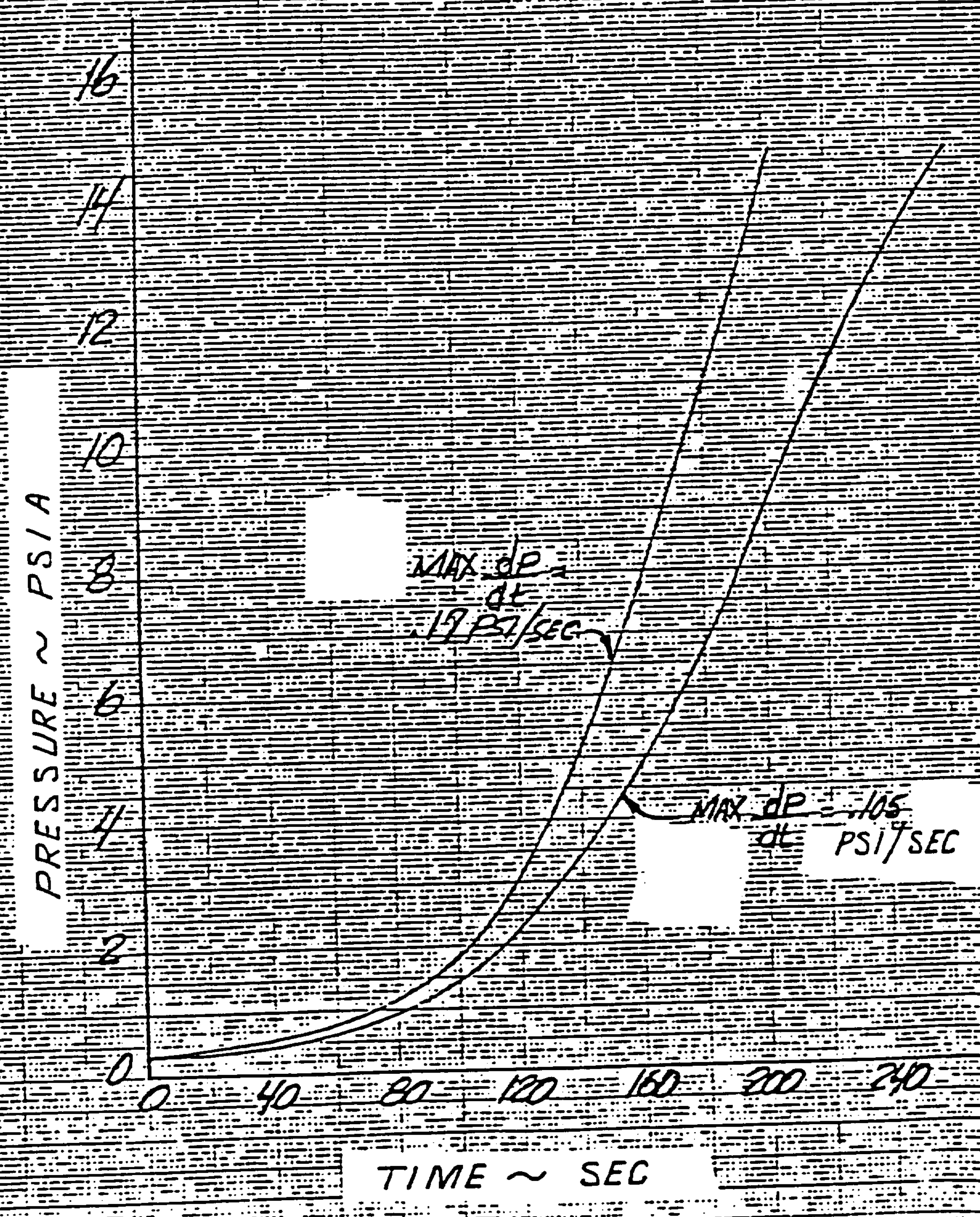
FIGURE 2

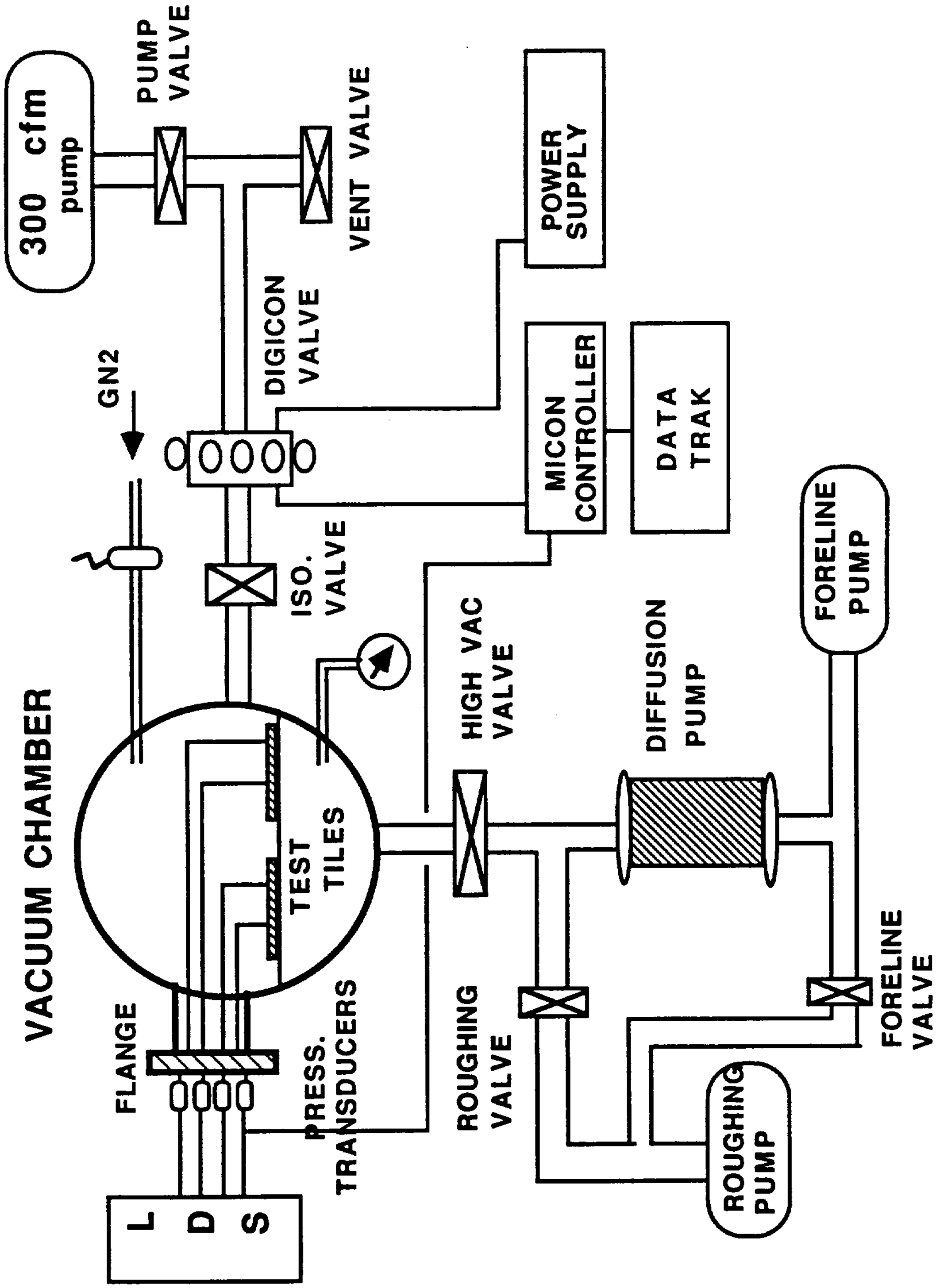


ORBITER ENTRY MISSIONS

AMBIENT PRESSURE BOUNDARIES

FIGURE 3





TEST SYSTEM SCHEMATIC